

# Kinematic Assessment of Subject Personification of Human Body Models.

Ana Piqueras Lorente<sup>1</sup>, Johan Iraeus<sup>2</sup>, Ana I. Lorente Corellanos<sup>1</sup>, Francisco J. López Valdés<sup>3</sup>, Óscar Juste Lorente<sup>1</sup>, Mario Maza Frechín<sup>1</sup>, Bengt Pipkorn<sup>2</sup>

<sup>1</sup> Impact Laboratory

Instituto de Investigación en Ingeniería de Aragón (I3A)

Universidad de Zaragoza, Mariano Esquillor s/n, 50018, Zaragoza, Spain.

Tel. +34-976762707, e-mail: [apiquera@unizar.es](mailto:apiquera@unizar.es)

<sup>2</sup>Chalmers University of Technology, Gothenburg, Sweden.

<sup>3</sup>Instituto de Investigación Tecnológica (IIT), ICAI, Universidad Pontificia de Comillas. Madrid, Spain.

## Summary

The aim of this study is to evaluate if model modifications increases the similarity between the predicted kinematic responses of a personalised human body model (HBM) and the measured response from post-mortem human subjects (PMHSs) in full frontal and nearside oblique impacts using contemporary restraints.

## Methods

A modified version of THUMS v3 model [1][2][3] was used in this study. To evaluate the kinematic response of this HBM, four PMHS sled tests in frontal and frontal oblique load cases were carried out [4][5].

## Instrumentation

The kinematic responses of the subjects were collected at 1 kHz using a 3D motion capture system (Vicon, TS series, Oxford, UK). Retroreflective markers were attached to selected locations of the subject, sled fixture and restraint system.

Four force transducers were installed in the upper and lower shoulder belt and the inner and outer lap belt band, recording the belt forces.

## Boundary Conditions

All simulations were carried out in the same conditions for each scenario. Sled acceleration pulses, obtained from the physical tests, were applied to the sled fixture in order to obtain the same loading scenarios. The parameters of the restraint system were adjusted to accurately represent the interaction between the seatbelt and the occupant, taking the belt forces from the real tests as reference.

## HBM Personification

The HBM was personalised in three steps. In each step, the level of complexity was increased. These modifications resulted in a total of six versions of the THUMS model for each crash scenario, the baseline model and five modified models with different levels of personification:

1. *Baseline*: The first level was to use the unmodified HBM as it is.

2. *Scaled mass*: In the second model, the overall mass was adjusted to represent the individual PMHS by scaling the density of the outer flesh properties.

3. *Morphed*: The morphing was carried out by means of Kriging interpolation. The module was included in the PIPER v1.0.0 software [6]. The PIPER software can estimate the missing dimensions based on a selected database (ANSUR; SNYDER or CCTANTHRO) using certain known anthropometry values as input variables.

4. *Baseline postured*: The baseline model was modified by aligning the spine curvature of the model to the actual spine curvature of the PMHSs at t=0ms.

5. *Scaled mass postured*: In this version of the model, both mass and posture were modified to resemble the weight and posture of the occupant.

6. *Morphed postured*: The posture of the morphed version (3) was adapted with the procedure followed for the model versions 4 and 5.

## Quantitative Assessment of the Kinematic Response

The assessment of the different versions of the HBM was done by comparing the trajectories in X, Y and

Z-axis of selected anatomical landmarks: head CoG, T1 and T8 vertebrae and H-Point for Scenarios 1 and 2 and left EAM, left shoulder and left knee for Scenario 3. The agreement between the predicted response and the sled test results was quantified using CORA v 4.0.4 [7]. CORA rating is a method to evaluate the time-history signals, the reference curve (physical test) and the predicted response (simulation). The total CORA score is expressed in a scale from 0 to 1, where 1 represents a perfect correlation and 0 represents no correlation.

## Conclusions

For the load cases included in this study, the more personalised the human body model was, greater the agreement between the predicted and measured kinematics. The personification have a grater influence when the HBM characteristics differ the most from the occupants.

Few improvements (only T8 and H-Point in the mass scaled model versions) were related to the lateral displacement of the observed anthropometric landmarks, thus the lateral kinematics were not sensitive to the studied personification strategies.

The lower spine kinematics is not being correctly predicted by the HBM and more effort should be done on the model validation.

This study demonstrates that the combination of the personification techniques improves the accuracy of the prediction of the occupant's kinematic and has the potential to cover a higher percentage of the population, which is not represented by the baseline models.

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**Table 1. Cora scores for the three crash scenarios**

MODEL VERSION	BASLINE	SCALED MASS	MORPHED	BASLINE POSTURED	SCALED MASS POSTURED	MORPHED POSTURED
<i>Scenario 1</i>	0.644	0.648	0.650	0.664	0.675	0.684
<i>Scenario 2</i>	0.638	0.653	0.688	0.673	0.704	0.715
<i>Scenario 3</i>	0.565	0.637	0.684	0.654	0.679	0.713